

**HEAT AND MOMENTUM FLUXES FOR HYCOM**  
**AN EXAMPLE APPLICATION : 3.2 km BLACK SEA MODEL**

By

**A. BIROL KARA, ALAN J. WALLCRAFT AND HARLEY E. HURLBURT**

**NAVAL RESEARCH LABORATORY (NRL)**

**STENNIS SPACE CENTER**

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>AUG 2003</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2003 to 00-00-2003</b>	
4. TITLE AND SUBTITLE <b>Heat and Momentum Fluxes for HYCOM: An Example Application: 3.2 km Black Sea Model</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Research Laboratory,Stennis Space Center,MS,39529</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>7th HYCOM Consortium Meeting, Aug 19-21, 2003, Camp Springs, MD</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>14</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## Contents

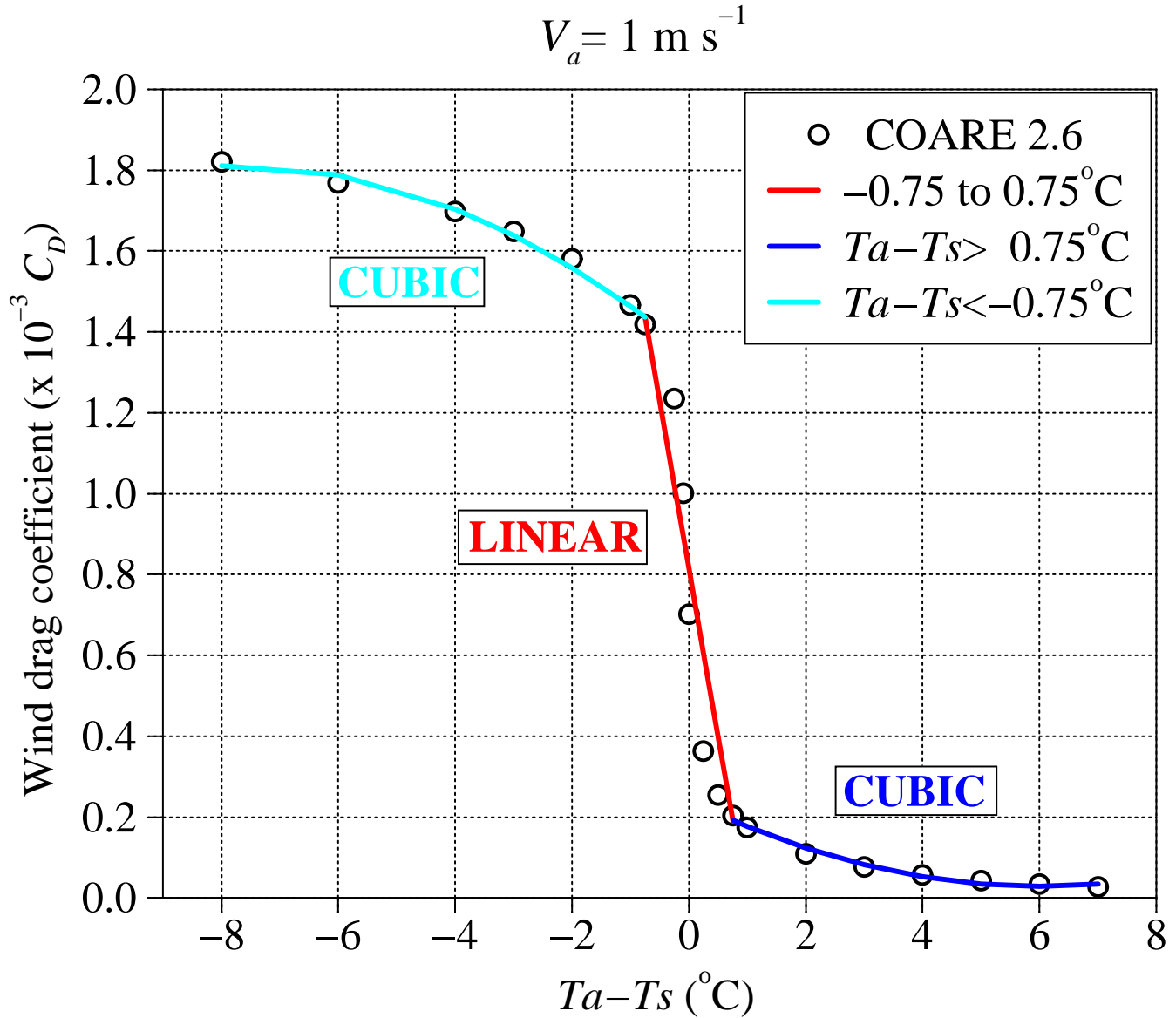
- Wind Stress
- Thermal Forcing
  - latent and sensible heat fluxes
  - shortwave and longwave fluxes
- The Black Sea Simulation
- Impact of Water Turbidity
- Summary and Conclusions

## Atmospheric Forcing

- Wind stress:
  - a bulk formula
  - air/sea stability on drag coefficient
- Latent and sensible heat fluxes:
  - bulk formulae
  - air/sea stability on exchange coefficients
  - calculated using HYCOM SST at each time step
  - realistic tendency towards the “correct” SST
  - keep the HYCOM SST on track
- Shortwave radiation at the sea surface
- Longwave radiation at the sea surface

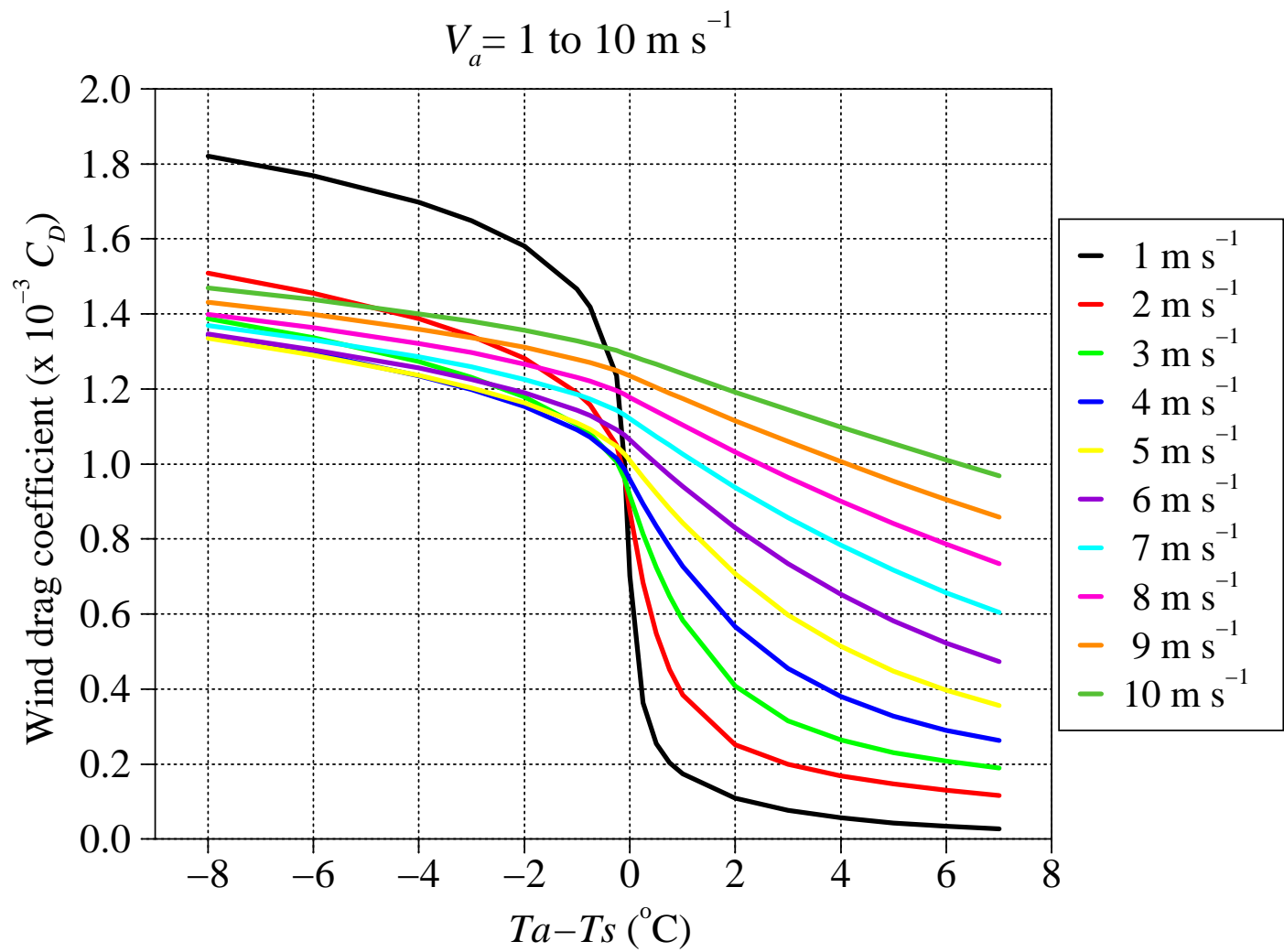


## WIND DRAG COEFFICIENT



- The methodology includes
  - stable case, unstable case, neutral case

# WIND DRAG COEFFICIENT FOR DIFFERENT WIND SPEEDS



## Shortwave Radiation Penetration

- Previous Subsurface Heating Parameterization in HYCOM

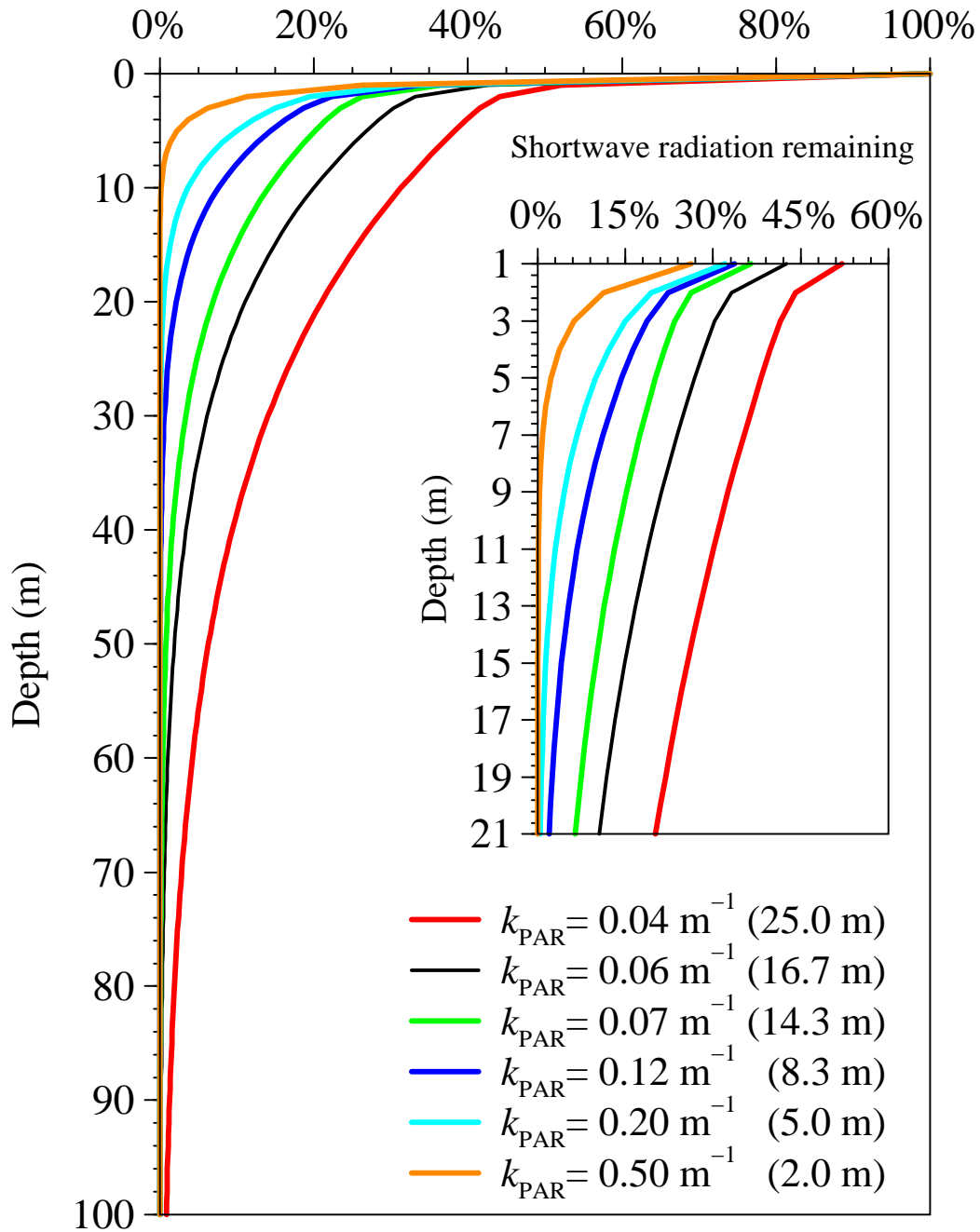
- few discrete attenuation profiles

	Type	Red (%)	Blue (%)
1	I	58	42
2	IA	62	38
3	IB	67	33
4	II	77	23
5	III	78	22

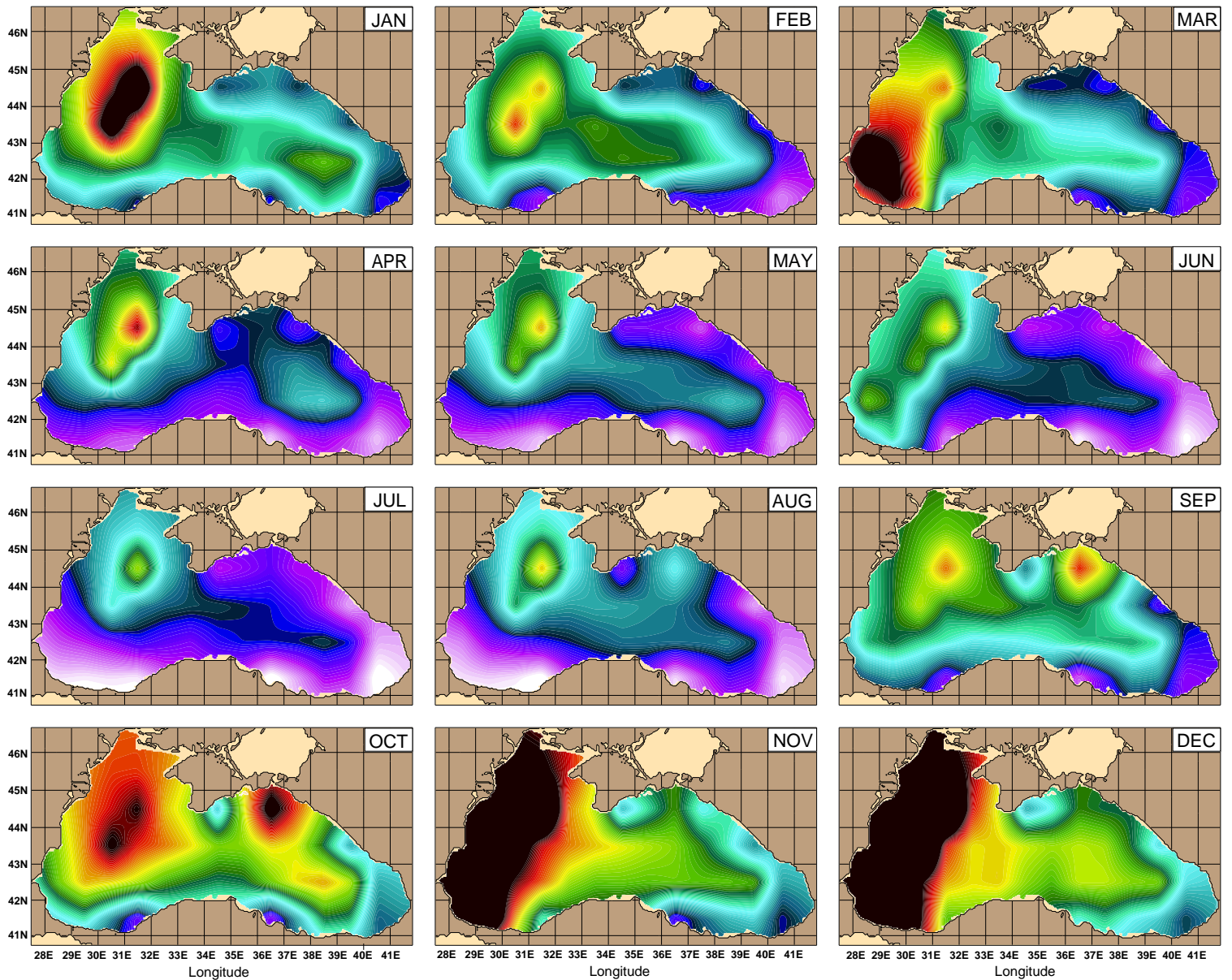
- A new shortwave radiation penetration scheme for HYCOM
- Different than “bulk type” mixed layer models
  - spatial and temporal water turbidity from SeaWiFS
  - 2–band scheme:
    - red spectrum: absorbed near surface
    - blue spectrum: more deeply penetrating

## SHORTWAVE RADIATION ABSORPTION

Shortwave radiation remaining below the sea surface



# ATTENUATION COEFFICIENT CLIMATOLOGY

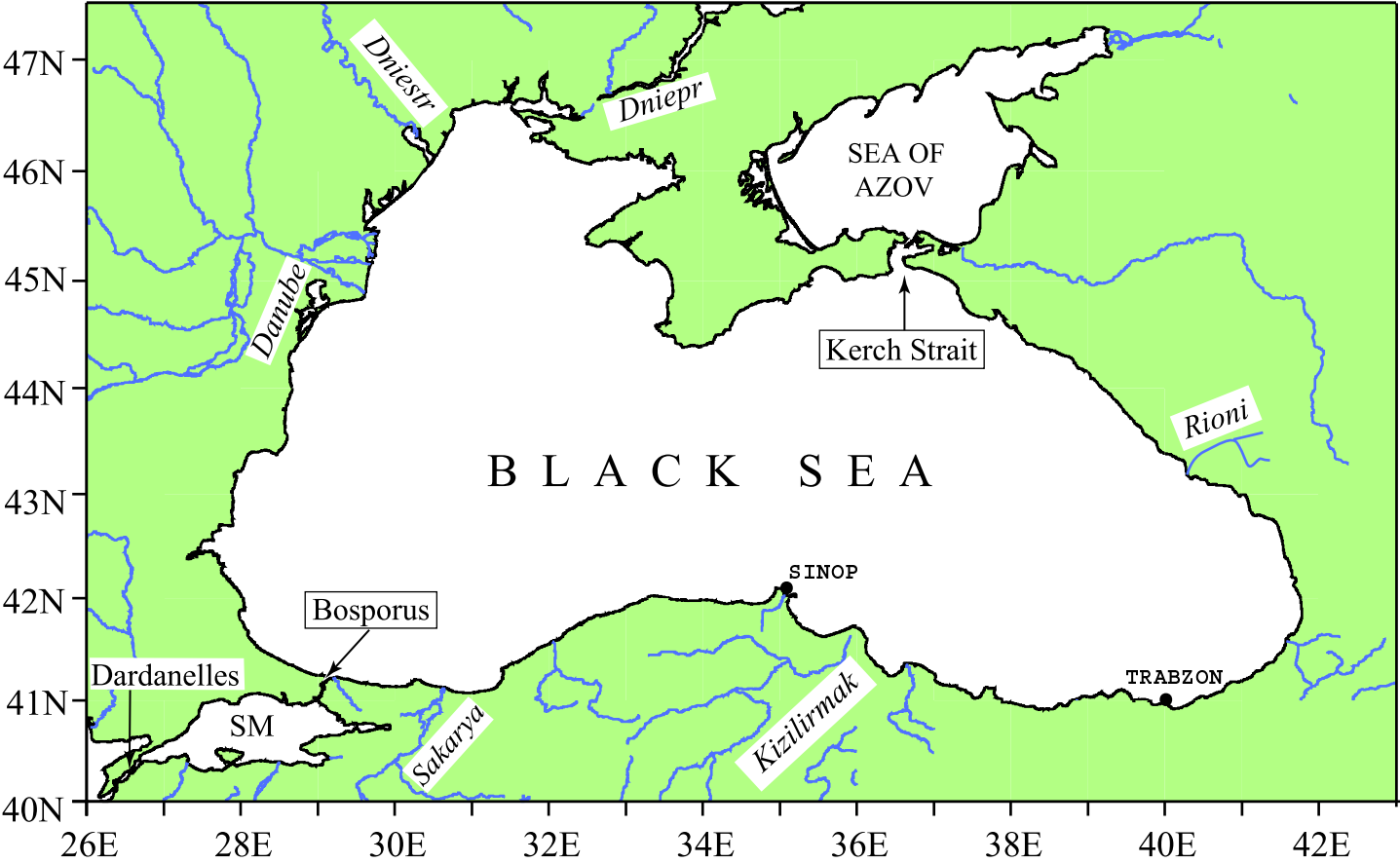


$k_{PAR}$  ( $m^{-1}$ )

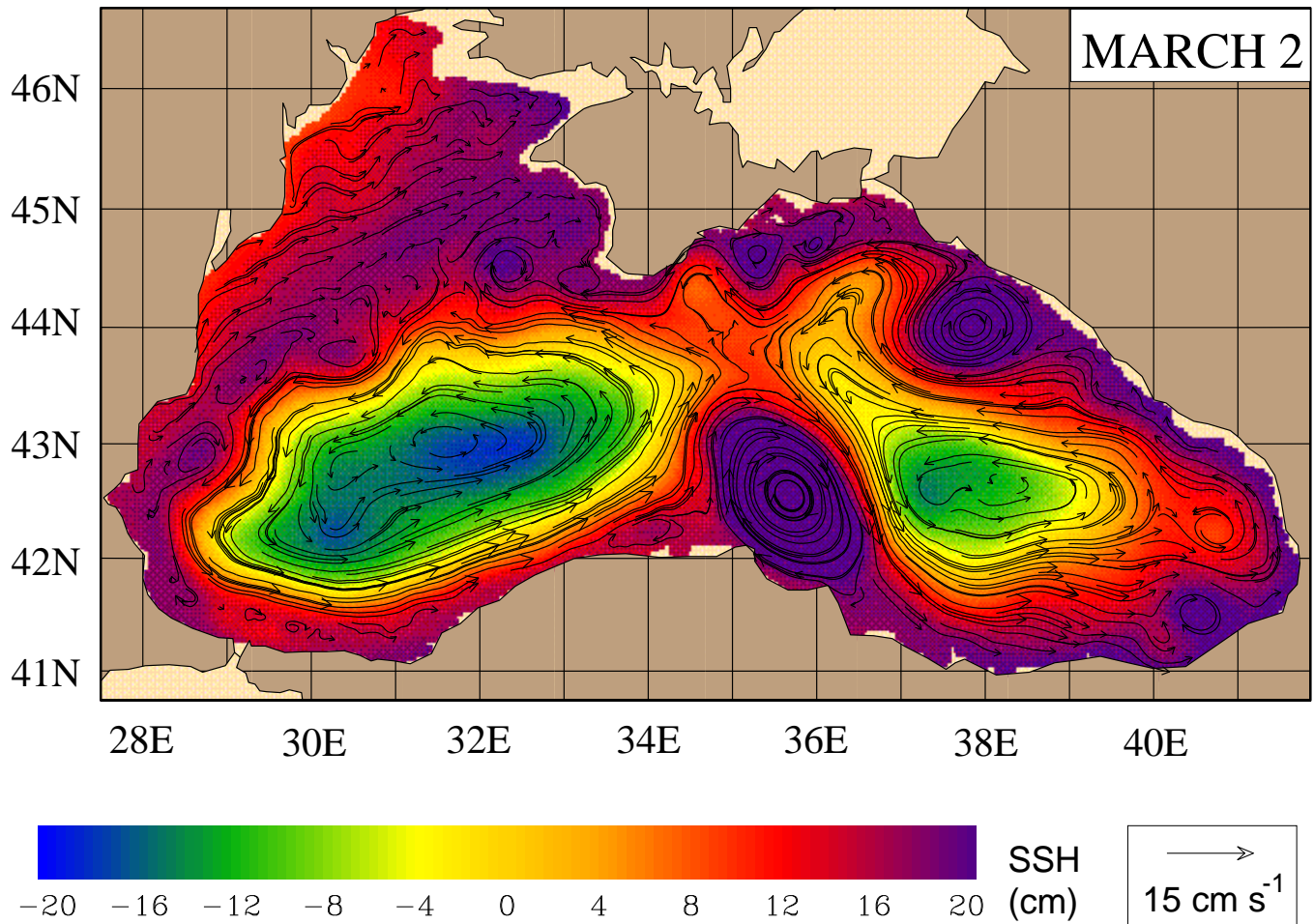
## Longwave Radiation

- A correction is needed. Why ?
  - Longwave radiation from ECMWF or NOGAPS
  - Calculated using their model SST
- HYCOM now uses
$$Q_{\text{LW}}(T_s) = Q_{\text{LW}}(T_c) - 5.3 (T_s - T_c).$$
  - $T_s$ : HYCOM SST
  - $T_c$ : Climatological SST
- A constant value:  $-5.3 \text{ W m}^{-2} \text{ C}^{-1}$  (relaxation term)

**GEOGRAPHY OF THE BLACK SEA**



## SNAPSHOTS OF SSH and SURFACE CURRENTS

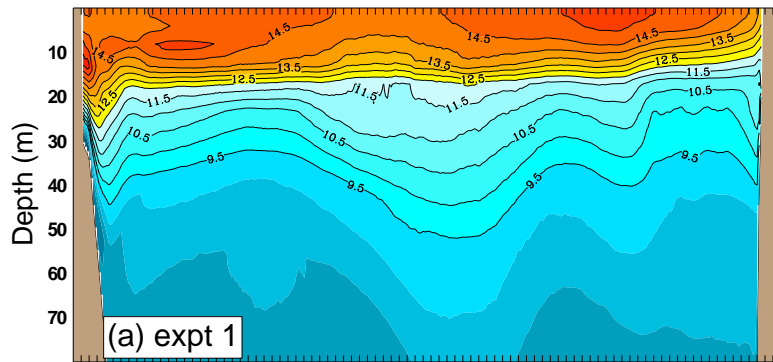


- Climatologically forced HYCOM simulation:
- Wind and thermal forcing from NOGAPS

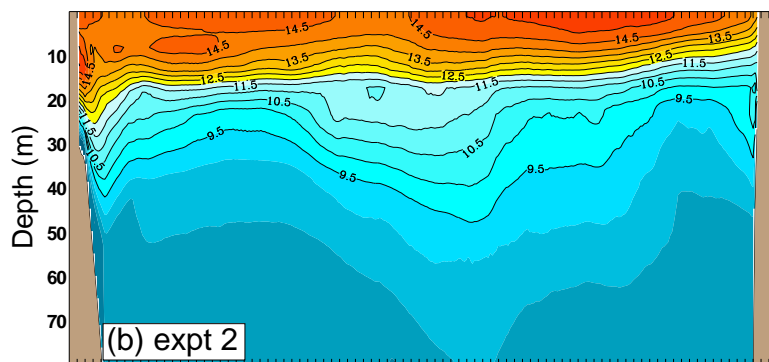
NOGAPS: Navy Operational Global Atmospheric Prediction System



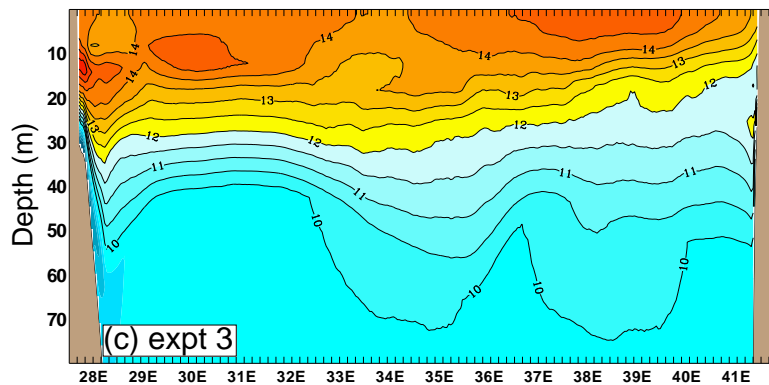
# ANNUAL MEAN SUBSURFACE TEMPS. ALONG 42.6°N



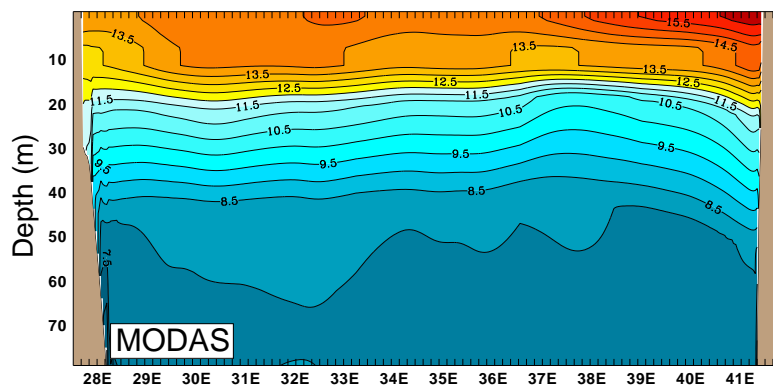
SeaWiFS BASED  
TURBIDITY



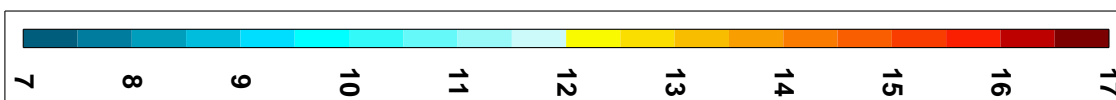
ALL RADIATION  
AT THE SURFACE



CLEAR WATER  
ASSUMPTION



MODAS TEMP.  
CLIMATOLOGY

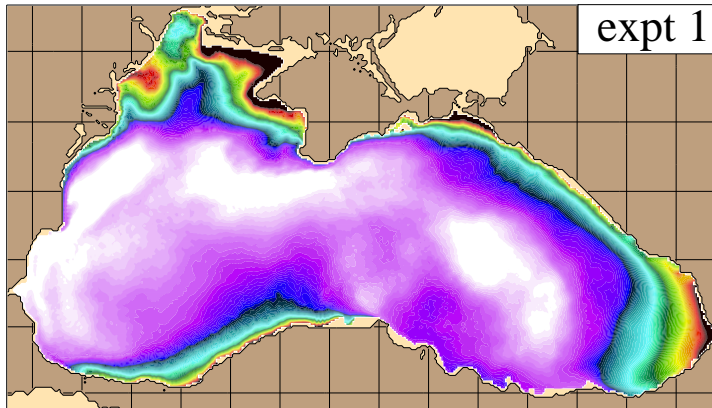


Temp. (°C)

## SST VALIDATION

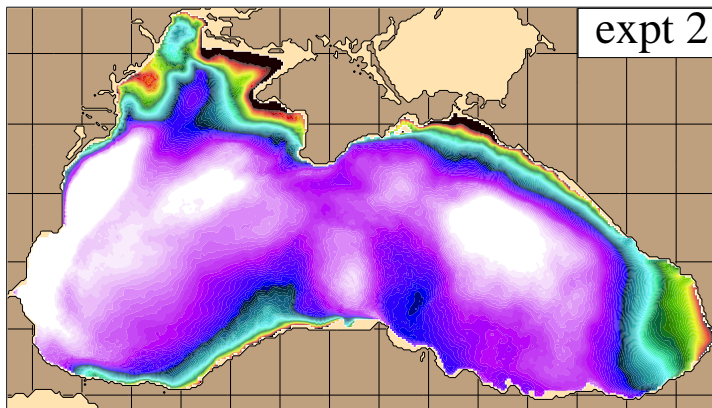
SST RMS difference with respect to the  $1/8^\circ$  Pathfinder SST clim.

12 monthly HYCOM SST versus 12 monthly Pathfinder SST



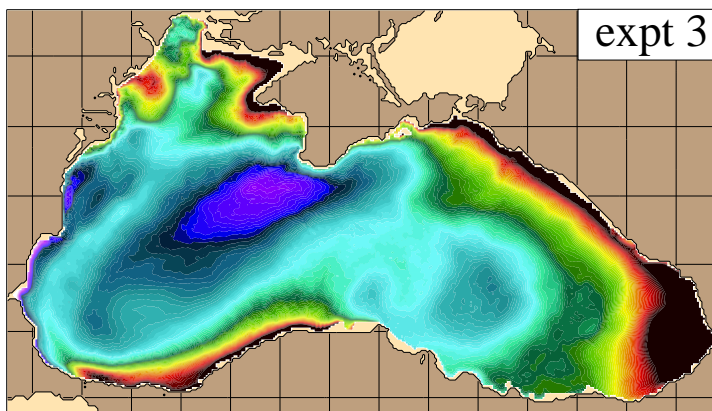
**SeaWiFS BASED  
TURBIDITY**

(RMS =  $1.41^\circ\text{C}$ )



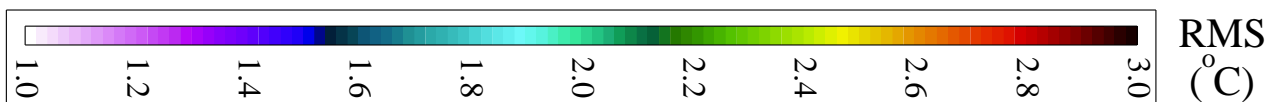
**ALL RADIATION  
AT THE SURFACE**

(RMS =  $1.42^\circ\text{C}$ )



**CLEAR WATER  
ASSUMPTION**

(RMS =  $2.06^\circ\text{C}$ )



## SST SKILL SCORE and LAND/SEA MASK

LAND/SEA MASK FROM ECMWF

